The NASA/JPL AIRSAR Integrated Processor

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Abstract - The NASA/JPL AIRSAR Integrated Processor (AIP) is a multi-frequency polarimetric and interferometric SAR processor designed for better understanding of scattering from different types of Earth terrain. The processor is utilized to automatically generate co-registered multifrequency images from both polarimetric and interferomeric data collection modes. When one frequency interferometric Digital Elevation Map (DEM) is available, all channel images of three-frequency are projected and terrain-corrected to the DEM. All AIP products are corrected geometrically, polarimetrically, and radiometrically . This paper describes the implementation of the operational AIRSAR Integrated Processor.

polarimetry
interferometry

I. Introduction

The NASA/JPL AIRSAR system is a three-frequency airborne SAR system that was developed as a general test-bed for various advanced SAR techniques. The AIRSAR was designed, built and is managed by the Jet Propulsion Laboratory (JPL), California Institute of Technology, for the National Aeronautics and Space Administration (NASA). The AIRSAR is flown on a NASA DC-8 passenger jet, modified for research applications, operated by NASA's Dryden Flight Research Center in Edwards, California. As part of NASA's Earth Science enterprise, the AIRSAR Integrated Processor (AIP) [1] data are currently collected for NASA-funded investigators in the United States as well as sponsors from international organizations. Calls for flight request are made on a yearly basis from NASA Headquarters, where the flight requests are also approved. Once the flight season is scheduled, JPL works with the selected investigators to optimize data collection. Following data collection, data are processed at JPL and then delivered to the customers. All processed data are archived and catalogued at JPL.

The AIP consists of the polarimetric SAR (POLSAR) [2] and topographic SAR (TOPSAR) [3] for the purpose of significantly improving our scientific understanding of scattering from different types of Earth terrain. The processor is utilized to automatically generate co-registered multi-frequency images regardless of polarimetric and interferometric data collection modes[4]. If one frequency interferometric Digital Elevation Map (DEM) is available, all channel images of three-frequency are projected and terrain-corrected on this DEM.

The AIP's POLSAR and TOPSAR capabilities provide data for a wide range of application, including archeology studies, biomass and soil moisture estimation, vegetation and land-use classification, slope estimation for landslide risk assessment, wetland classification, natural hazard monitoring and studies, geologic mapping, and glacier studies.

II. AIRSAR System

The AIRSAR [5] is a left-looking radar simultaneously operating at three wavelengths: C-band (0.057 meter), L-band (0.25 meter), and P-band (0.68 meter). The AIRSAR operate in the following three modes: POLSAR mode, XTI mode and Along-track Interferometric (ATI) mode. POLSAR is fully polarimetric meaning that radar waves are transmitted and received in both horizontal and vertical polarization. The SAR interferometry is a method of operating the radar such that two data sets of the same area are collected simultaneously via two identical antennas separated by a fixed distance. The AIRSAR can collect two kinds of XTI data. The single-baseline cross-track interferometric mode has only one antenna transmitting radar pulses. The dual-baseline cross-track interferometric mode has both antennas transmitting and receiving radar pulses. In addition there are two antennas separated in the horizontal direction along the flight path used in the along-track interferometric mode to detect ocean current movement.

III. AIP Requirements

The requirements of the operational AIP [6] are that it supports the POLSAR and TOPSAR data acquisition modes operated in the 20 MHz or 40 MHz bandwidth. The processor has the capability to generate both slant range and ground range images, and it provides motion compensation, polarimetric, radiometric and geometric calibration facilities. The requirements of the operational throughput rate is to produce 18 frame images weekly. The size of a frame image is defined as a 10 km x 10 km dimension. Strip products, up to 60 km along track, can be also generated.

The design goal of the AIP is to develop the processor in a way such that it can accommodate future upgrades and be easy to operate and maintain and port to other popular Unix-based or Intel NT-based platforms. The emphasis is on applying to the greatest extent possible commercial Off-the-Shelf hardware, software, and technology.

IV. AIP Implementation

To co-register the L-band and P-band POLSAR with the C-band TOPSAR data, we process the data to single-look range-Doppler then deskew them across frequencies.

Each frequency is processed with the optimum patch size in terms of processing efficiency and motion compensation accuracy [3].The AIP software system comprises Pre-processor, Range-Doppler module, TOPSAR module, POLSAR module, and Quality Assurance module. The description of each module of the AIP is shown as follows.

4.1 Pre-processor

The pre-processor consists of radar mode parameters generation, radar motion parameters[3] generation, Doppler parameters generation for each patch, global reference line, and DEM location reference point modules.

4.2 Range-Doppler Image Generation

The Range-Doppler module performs the range compression, range migration correction, motion compensation processing, azimuth compression, and deskew processing for every patch segment[3].

4.3 TOPSAR Processing

TOPSAR processing [4] takes two antennas of single-look range-Doppler images as input then performs the inteferometric phase unwrapping and generates the following four output files such as DEM, correlation coefficients, scattering area, and incidence angle. In the meantime, the radiometric and geometric compensation processing are performed on the intensity image of each pixel. All of these five output files are projected on the WGS-84 datum.

4.4 POLSAR Processing

Once the four polarization channels (hh, hv, vh, and vv) have been processed to form the complex range-Doppler image, the POLSAR processing performs the radiometric and geometric compensation functions and the multipolarization scattering matrices for each resolution element in a scene. The data are then compressed to JPL's Stokes scattering operator format with 10-byte per pixel[4]. In addition, the ground range projection is formed if C-band DEM data are available.

4.5 Quality Assurance

The Quality assurance module (QA) of the AIP is a menu-driven user interface designed to simplify the operation tasks with menus for Monitoring, Job Submission, Archiving and Data Analysis. The monitoring feature is designed to oversee the progress of the QA processes. In order to ensure that consistent and trouble-free products result from each AIP run, the QA processes normally go through checkpoints of validation. The first step of verification is to check the data format of each the 12-channels. To submit a processor job, a setup program generates a profile of the run. At this point, a pre-QA process is carried out with raw data histogram, chirp spectrum, calibration tone estimate and motion data plots to validate the raw data. After the range-Doppler processing, the co-registration verification is conducted. For the TOPSAR, ground control points are provided to validate each DEM. The 1996 Pac-Rim TOPSAR DEM quality satisfies our prediction, which is 1-3 meter height accuracy for flat areas[7]. For the POLSAR data, the angle of hh-vv and signature are measured for each scene[6]. The delivery media of the AIP products is either an universal ISO9660 CD-ROM or 8 mm data tape and image color prints are also provided to customers. A customer ordering system merging with the geographic map server, relational database, and internet Web browser is under construction.

4.6 Throughput Rate

The AIP resides in a parallel 8-cpu multi-processor Power Challenge Unix-based machine from Silicon Graphics, Inc. (SGI). The SGI software supports comprehensive sets of the parallel concurrent library.

In order to meet the requirement of 18 frame image per week, both the coarse-grain and fine-grain parallel computing methods are utilized in the AIP[8]. The fine-grain parallelization is usually the approach taken by vendor supplied parallelization routines. This model of the fine-grain parallelism used focuses on the Fortran DO loop. The compiler executes different iterations of the DO loop in parallel on multiple processors. The coarse-grain model re-allocates the computer system resources into a number of independent processor to associate a number of the independent data segments. The coarse-grain model is a more efficient approach but requires deeper knowledge of the program structure which we used in the patch mode Range-Doppler image generation module. For the patch-mode Range-Doppler processing, the raw data can be divided by the azimuth lines of each processing job into a number of equal-size patches. Then to assign each CPU to process equal numbers of patches data Independently. The fine-grain parallelization is applied to both POLSAR and TOPSAR modules. The average throughput rate of the AIP now reaches to 40 frame images per week including all QA procedures. It takes 8 minutes to process one channel frame data. The standard product size of the AIP are 10, 20, 30, 40, 50 , and 60 km in the along-track. In addition, the raw data down-load Sony HDDT tape [9] module performs a 8.2 Mbyte/sec throughput rate with parallel techniques.

V. Summary

In this paper we described the implementation of the AIRSAR Integrated Processor to automatically produce co-registered multi-frequency images of POLSAR, TOPSAR, or mixed mode (a combination of polarimetric and interferometric modes). All AIP products are calibrated in polarimetry, radiometry and geometry for each image pixels. In late 1996, the AIRSAR was flown over selected sites in 10 countries in south-east Asia. Several examples of these data will be given during this presentation.

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